

cathodic potentials.
passivity as indicated by

difference in average
eature is that at high
2 mm per year (8 μ A)

ded in cementitious
Evans diagram.

and penetrating
cement pastes with
steel embedded in

ment and Concrete
ee and Dr. S.L. Mak

Chapter 1 in Corrosion
17.

in Concrete, Ed. P.
ondon, pp. 3-21, 1988.

ZEOLITE CRYSTALLIZATION IN PORTLAND CEMENT CONCRETE

DUE TO ALKALI-AGGREGATE REACTION

Marfil S. A.^(1,2) and Maiza P. J.^(2,3)

- (1) Dpto. de Geología. Universidad Nacional del Sur. Bahía Blanca. Argentina.
- (2) CIC. Comisión de Investigaciones Científicas de la Prov. de Buenos Aires.
- (3) CONICET. Consejo Nacional de Investigaciones Científicas y Técnicas.

(Refereed)

(Received April 22, 1991; in final form August 13, 1993)

ABSTRACT

Concrete used in works and altered by alkali-aggregate reaction was studied in order to identify the reaction products. For this purpose, the methods of petrographic microscopy, XRD and SEM were employed.

The crystalline forms observed by SEM were later determined through the petrographic microscope, as being zeolites on the basis of their optical properties and confirmed by XRD. In order to obtain a minimum amount (10 mg) of the reaction product, many thin sections were prepared. The product was isolated under the microscope for XRD analysis, through which it was identified as being a zeolite (heulandite-clinoptilolite group).

With the aim of determining the minimum limits capable of being registered by XRD, tests with the addition of 1, 5 and 10 % of a similar natural zeolite (clinoptilolite) were also performed on a concrete sample, showing that 5 % is about the minimum.

Introduction

The difficulty in the identification of the alkali-aggregate reaction products is mainly due to the poor crystallinity they display and to the low proportion in which they occur, resulting in a very difficult isolation for the subsequent XRD analysis. The preparation of thin sections of altered concretes used in works and of mortar bars has allowed us, on the basis of their optical properties, to identify the reaction products as zeolites (1). Those products occur filling voids or within fissures, with a random distribution of the crystals in the former case and perpendicular to the trend of the fissures in the latter.

In the current research, XRD was used with the purpose of achieving a clear-cut identification of the reaction products. The problem with that technique

is to isolate enough pure material so as to obtain a good diffractogram. In general, zeolite reflections results are masked by other minerals that are present in larger proportions, such as quartz and feldspar (belonging to the aggregate) and calcite (which always occurs at the surface of concrete).

Methods

The samples were observed with a petrographic microscope, the neo-formation product was identified and the areas of higher concentration were located for their subsequent extraction, placing special care on purity. The reaction products were analysed by XRD, using a Rigaku Denki diffractometer, Geigerflex D-max IIC, with Cu(K α) radiation and Ni filter at 45 Kv, 20 mA. Additionally, the products were observed in a JEOL JSM 35 CF SEM in order to determine the crystalline forms.

Results

Ten thin sections were prepared from a concrete altered by alkali-aggregate reaction with the purpose of achieving a sufficient concentration of material so as to be analysed by XRD. The samples are highly fissured. The microfissures, as well as the voids, are filled with a mineral that was identified as a zeolite on the basis of its optical properties (low birefringence, positive elongation, and very low refractive indices, between 1.47 and 1.48). Those zeolites that replace the reactive clasts, are randomly distributed in voids (Photomicrograph N° 1) and grow perpendicularly to the fractures (Photomicrograph N° 2). The edges of the quartz clasts with undulatory extinction are zeolitized (Photomicrograph N° 3).

Two reaction zones may clearly be noticed in photomicrograph N° 4: an external one, where the zeolite crystals are perfectly defined, and an internal zone, which still remains amorphous.

For the XRD analysis, it was possible to isolate, by picking under the microscope, 10 mg of the reaction product from the ten available thin sections. The material was dispersed with acetone on a glass slide. Table I shows the reflections obtained where, besides the quartz ones, those corresponding to clinoptilolite can be observed. They are compared with card JCPDS 39-1389, with a structural formula similar to $\text{KNa}_2\text{Ca}_2(\text{Si}_{12}\text{Al}_{17})\text{O}_{72}\cdot 32\text{H}_2\text{O}$, of the monoclinic system. The corresponding diffractogram is shown in figure A.

The material was examined by SEM (photomicrographs N° 5 and N° 6) where the most common crystalline forms, resembling the monoclinic system, can be seen.

With the purpose of defining the minimum detection limits for zeolite by XRD, a concrete sample was worked with the addition of 1 %, 5 %, and 10 % of a natural zeolite of similar composition. Clinoptilolite was used in this case, which was identified by XRD (JCPDS 39-1389). (Table N° II). The results with the addition of 1 %, 5 % and 10 % zeolites are shown in Table N° II and figure B.

With the addition of 1 % zeolite (Figure B1), the large reflection (8.95 Å, $2\theta = 9.88^\circ$) is very small, while the remainder corresponds to quartz and feldspar. With 5 % addition (Figure B2), other reflections, besides those of intensity 100, also appear. And with 10 % (Figure B3), zeolite is clearly identified. The diffractogram of the zeolite isolated under the microscope corresponds to that obtained by adding 10 % clinoptilolite to a concrete sample, although differences in crystallinity must be taken into account.